1,020,190

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,020,190

Date of Application and filing Complete Specification Sept. 2, 1964.
No. 35944/64.
Application made in Switzerland (No. 10919) on Sept. 3, 1963.
Application made in Switzerland (No. 9691) on July 24, 1964
Complete Specification Published Feb. 16, 1966.
© Crown Copyright 1966.

Index at acceptance:—B1 R9
Int. Cl.:—C 10 k

COMPLETE SPECIFICATION

Improvements relating to Liquid/Vapour Material Exchange Columns

We, SULZER BROTHERS LIMITED, a Company organised under the Laws of Switzerland, Winterhur, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to processes of material exchange between a liquid and a vapour comprising passing the liquid downwards and the vapour upwards through a material exchange column containing packings. Such processes include distillation, rectification, absorption, extraction and chemical reactions, such as the separation of isotope elements from a substance by a chemical exchange reaction, and the like.

The use of fabric packings, for instance wire-fabric packings helps to considerably increase the number of theoretical plates in a column as compared with when imperforate packings, for instance of sheet metal, are used, mainly because it is difficult for a uniform film of liquid to be formed on imperforate packings, more particularly because of the formation of rivulets, but with fabric packings the liquid runs over the packings in the form of a film which covers the "pores" uniformly. Another advantage of fabric packings is that the material exchange with the vapour phase can proceed on both sides of the liquid film covering the pores and is therefore much greater than with other kinds of packing.

When the convention fabric packings are used, made of plain weave wire cloth having square meshes, with the warp and weft wires of identical thickness, the liquid film spread over the fabric can be kept stable only during operation—i.e. the liquid (e.g., the reflux in rectification processes) descends in a uniform film over the packings. Statements have been made about the size and design of mesh shapes with the alleged view of helping to provide a stable film during operation; nevertheless, all these conventional kinds of packing must be flooded before operation begins —i.e. the packings must be washed with liquid before operation starts in order to first form the film of liquid on the fabric. In laboratory conditions it may readily be possible to flood the packings in the material exchange section of a column without any great outlay, but this must be regarded as exceptional for industrial columns and, where used, is associated with considerable outlay, for instance of a constructional nature. For instance, in the case of rectifying columns large quantities of reflux liquid must be stored continuously for the required flooding and must be available before rectification starts. With many mixtures, more particularly organic mixtures, the risk of thermal decomposition makes the conventional form of flooding impossible. Unfortunately, the number of theoretical plates which can be provided in a column having unflooded packings is very reduced. For instance, the number of theoretical plates which can be provided in an unflooded column of 5 cm diameter is only about 50% of the number which can be provided in a flooded column, whilst an unflooded column of 20 cm diameter can provide only about 20% of the number of theoretical plates of a flooded column of the same diameter.

According to the present invention, a process of material exchange between a liquid and a vapour comprises passing the liquid downwards and the vapour upwards through a material exchange column containing packings of a fabric which are wettable by the

[F

liquid and of which the ratio of the thread diameter d to the width of mesh opening a is such that at least in the weft thread direction or in the warp thread direction the product $\frac{\sigma_L}{\psi_L} \cos.\phi \frac{d}{a}$ (in which σ_L is the surface tension in dynes/cm of the liquid in contact with its vapour, ψ_L is the density of the liquid in gms/cu.cm, and ϕ is the wetting angle of the liquid on the threads) is at least 38, the diameter of the warp threads and the weft threads being 0.6 mm or less.

When the packing fabric has these characteristics a wetting film of liquid forms more easily on the fabric from the liquid descending in the column so that previous flooding of the packings may be reduced or may be unnecessary.

According to another aspect of the present invention, a packing component for a material exchange column comprises or consists of fabric having unobstructed mesh openings and having dimensions such that, at least in the weft direction or in the warp direction, the ratio d/a of the thread diameter d to the width of mesh opening a is greater than 1 and does not exceed 2.5 and the diameter of neither the weft nor the warp exceeds 0.6 mm.

The various characteristics of the fabric will now be discussed.

A wetting film of liquid forms on the fabric meshes when, as the liquid descending the column trickles on to the packings, the capillary forces produced in the fabric meshes suffice to wet the fabric completely and to spread a film of liquid over the mesh surfaces. The wetting angle ϕ which a liquid in a capillary forms with the fixed boundary wall thereof must of course be less than 90° for a positive capillary action to occur (Fig. 1*a*); when $\phi > 90°$ there is no wetting (Fig. 1*b*). It is therefore essential that the fabrics used for manufacturing the packings are made of such materials as are wetted by the treated liquids. Preferably, the substances used are metallic substances whose self-wetting properties can be provided, if required, by surface roughening or by the application of a porous material, such as silica colloids. However, other sufficiently dimensionally stable inorganic or organic materials, such as glass or plastics, can be considered.

Once the surface tension σ_L and the wetting angle $\phi < 90°$ for a liquid are known, the rise h in a capillary can of course be calculated. This does not apply to a fabric since it is impossible to determine the quantity of liquid between the threads which, in the case of a metal fabric, are wires. Experiments made in connection with the invention show that the capillary forces of a fabric increase in proportion to the quotient formed by the thread diameter and the thread spacing. In other words, the capillary forces in the fabric meshes are greater in proportion as thread diameter is greater and thread spacings are smaller. There are economic limits to this condition, however, which make it necessary, more particularly in the case of fabrics of metal wires, to have very small wire diameters and very large mesh sizes. Our experiments were therefore limited to filament or wire diameters of 0.6 mm or less.

Another experimentally determined factor behind the invention is that packings are self-wetting if the thread diameters d and the thread spacings a are so chosen in at least one direction of the fabric that the liquid between the wires rises by at least 1 mm above the liquid level in a test rig in which wires of diameters d are stretched out parallel with one another at spacings a and are immersed in a liquid bath. A test rig of this kind is diagrammatically shown in longitudinal section and cross-section in Figs. 2*a* and 2*b* respectively. Experiments confirm that in these conditions, if there is a continuous supply of liquid from the top of a column on to the packings in the material exchange section, there is complete wetting of the packings.

The invention resides in the discovery of a formula governing the dimensioning of a self-wetting fabric having unobstructed mesh apertures or pores for packings. In determining the dimensions of the fabric to be used for a process according to the invention, the surface tension σ_L in dyne/cm of the liquid in contact with its vapour, the liquid density ψ_L in g/cm³ and the cosine of the wetting angle ϕ are first found, whereafter the ratio of the thread diameter d to the internal mesh size a is so chosen at least in the weft thread direction or warp thread direction that the product $\frac{\sigma_L}{\psi_L} \cos \phi \frac{d}{a}$ is at least 38, with the proviso that the diameter of the warp threads and of the weft threads is 0.6 mm or less.

An alternative way of expressing the characteristics of the fabric is to say that, at least in the weft thread direction or in the warp thread direction of the fabric, the product of a physical property-dependent factor A with a geometry-dependent factor B is at least 38, the factor A being formed from the quotient of the said surface tension σ_L in dyne/cm divided by the liquid density ψ_L in g/cm³, multiplied by the cosine of the wetting angle ϕ, while the factor B is formed from the ratio of the thread diameter d to the mesh size a in the given direction, with the proviso that the diameter of the warp threads and of the weft threads is 0.6

mm or less. Putting this as a mathematical relationship, we can state:

$$A \cdot B \geqq 38,$$

where

$$A = \frac{\sigma_L}{\psi_L} \cos \phi$$

and

$$B = \frac{d}{a}$$

in which:

σ_L=the surface tension of the liquid in contact with its vapour in dynes/cm

ψ_L=the density of the liquid in gms/cm³

ϕ=the wetting angle in degrees

d=the wire diameter in cms

a=the wire spacing in cms

The number 38 also leads to an optimum —i.e., very large—spacing *a* for mesh size. The values for liquid density and surface tension in contact with the vapour phase are often very uncertain, but this uncertanty can be circumvented by a reduction of the mesh size *a*. The numerical value of the product A . B then increases, so that conditions for self-wetting of the fabric improve. However, if the mesh size is reduced very much, the efficiency of material exchange may be greatly impaired.

An advantageous development of the invention is, therefore, the discovery of a formula governing a bottom limit for the mesh size *a*, to ensure satisfactory material exchange. It has been found from experiments conducted on fabrics that to meet this requirement the dimensions of the thread diameter *d* and of the mesh size *a* are preferably such that the quotient $d/a \leqq 2.5$. This quotient is preferably at least 1.2.

The invention is of use both with statistical packings—i.e. packings whose total surface forms a random structure—and with regular packings—i.e., packings whose surface has an ordered structure. Typical statistical packings are, for instance, Raschig rings and saddle elements, and typical regular packings, are, for instance, wound members of wire fabric of the same diameter as the column.

With practically all the known liquids, including condensed gases the values of σ_L, ψ_L and ϕ are always such that, to meet the formula A . B≧38, the ratio d/a must be greater than unity. Commercially available wire fabric packings are produced with a 1×1 linen weave—i.e., each weft filament is completely tied into the warp and *vice versa*, the warp filaments and weft threads being wires of the same diameter as one another. This kind of fabric does not and cannot meet the requirement stipulated by the invention of d/a>1.

The following example shows that the capillary forces required for self-wetting in accordance with the formula A . B≧38 cannot occur in this kind of fabric.

Taking the liquid methylcyclohexane as an example, its density ψ_L=0.769 g/cm³, its surface tension ψ_L=23.8 dynes/cm and the wetting angle ϕ=0, assuming that phosphor-bronze wire is used. The packings used are 6×6 mm commercially available rings—i.e., rings whose height and diameter are 6 mm —they are made of plain weave wire cloth with the following dimensions:

d=0.011 cm

a=0.014 cm.

When we introduce these values into the formula for A . B, the result is 24.4—i.e., the wire fabric does not have the required capillary action. This result is confirmed experimentally.

However, when the same experiment is repeated but using a wire fabric having the dimensions:

d=0.016 cm

and

a=0.0077 cm in the direction of the warp wire, as diagrammatically shown in Fig. 3, the value calculated by our formula is 67.5. In other words, this wire fabric definitely has the required capillary action. Actually, in an experiment in which a fabric of this kind is immersed in methylcyclohexane, the liquid rises some 4 to 5 mm between the weft threads. The experiment shows that packing rings made of this fabric provide the same number of theoretical plates without flooding as are provided by the conventional packing rings with previous flooding. Also, the quotient d/a is 2.1, so that the material-exchange properties of the fabric are satisfactory.

In another example, it is required to find the dimensions of a fabric to be used for the packing of a rectifying column in which it is required to separate a mixture of cis-decalin/trans-decalin at 100° C. This liquid has a density ψ_L=0.79 g/cm³ and a surface tension σ_L=24 dynes/cm. The wetting angle ϕ=0 if non-rusting steel is used. When these values are introduced in the formula A . B≧38, we find that the quotient d/a must be ≧1.1 for the fabric to be self-wetting. For satisfactory material exchange, the condition $d/a \leqq 2.5$ must also be met.

In other words, d/a must be somewhere between 1.1 and 2.5. Since as already stated the numerical values of the physical properties to be used in the formula have an uncertainty factor, it is advisable in this case for d/a to be about 1.6, in which event, if the wire diameter *d*=0.016, cm, *a* must be 0.010 cm.

A satisfactory capillary action can be provided if the formula is operative in only one direction of the mesh—i.e., if the spacing *a* between the weft threads is in the required relationship to the thread diameter *d*, it is

immaterial for the capillary action by how much the spacing b between the warp threads are greater than the wire diameters.

Fabrics in which the warp and weft are of the same diameter, being easy to manufacure in the required size and design, are likely to be mainly considered for packings, but for the purposes of the invention, fabrics of this kind must have rectangular mesh shapes. However, in wire fabrics whose warps and wefts are of different diameters, the process of the invention can be performed with square mesh shapes. For instance, in the wire fabric shown in Figure 4 the area of each mesh is a^2, and d/a>1 in the weft direction.

Naturally, the required characteristic can be provided in both the weft thread direction and the warp thread direction. One such wire fabric is shown in Figure 5.

Figure 6*a* is a diagrammatic plan view—and Figures 6*b* and 6*c* are two side elevations of one very advantageous kind of wire fabric for packings which can meet the dimensioning requirements of the invention and which also have a satisfactory mechanical strength, something which is vital for the manufacture of the packings, and for their dimensional stability. This fabric is a so-called five-heddle fabric—i.e., every fifth warp and every fifth weft is tied in, the ties of consecutive wefts each being staggered relatively to one another by one warp. The warp and weft of this fabric are of the same diameter and the spacing a between the wefts determines the capillary action.

Advantageously, the packings are regular stacked packings and are arranged so that the width of mesh opening a is measured in the vertical direction between two horizontal threads, one above the other, i.e., the smallest mesh spacing a is between two superjacent horizontal wires or filaments.

WHAT WE CLAIM IS:—

1. A process of material exchange between a liquid and a vapour comprising passing the liquid downwards and the vapour upwards through a material exchange column containing packings of a fabric which are wetted by the liquid and of which the ratio of the thread diameter d to the width of mesh opening a is such that at least in the weft thread direction or in the warp thread direction the product $\frac{\sigma_L}{\psi_L} \cos\phi \frac{d}{a}$ (in which σ_L is the surface tension in dynes/cm of the liquid in contact with its vapour, ψ_L is the density of the liquid in gms/cu.cm. and ϕ is the wetting angle of the liquid on the threads) is at least 38, the diameter of the warp threads and the weft threads being 0.6 mm or less.

2. A process as claimed in Claim 1 in which the fabric has dimensions such that the ratio d/a of the thread diameter d to the width of mesh opening a is 2.5 or less.

3. A process as claimed in Claim 2 in which the ratio d/a is at least 1.2.

4. A process as claimed in Claim 1 or Claim 2 or Claim 3 in which the fabric is a five-heddle weave in which every fifth thread of the warp and of the weft is bound in.

5. A process as claimed in any of the preceding claims in which the packings are regular stacked packings and are arranged so that the width of mesh opening a is measured in the vertical direction between the two horizontal threads, one above the other.

6. A process of material exchange between a liquid and a vapour as claimed in any of the preceding claims and employing a fabric substantially as described herein with reference to Figure 3 or Figure 4 or Figure 5 or Figures 6*a*, 6*b*, and 6*c* of the accompanying drawings.

7. A wettable packing component for a material exchange column comprising or consisting of fabric having unobstructed mesh openings and having dimensions such that, at least in the weft direction or in the warp direction, the ratio d/a of the thread diameter d to the width of mesh opening a is greater than 1 and does not exceed 2.5 and the diameter of neither the weft nor the warp exceeds 0.6 mm.

8. A packing as claimed in Claim 7 in which the fabric is a five-heddle weave in which every fifth thread of the warp and of the weft is bound in.

9. A packing as claimed in Claim 7 or Claim 8 in which the fabric is of metal, glass or plastics.

KILBURN & STRODE,
Chartered Patent Agents,
Agents for the Applicants.

Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1966.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

Fig. 1a

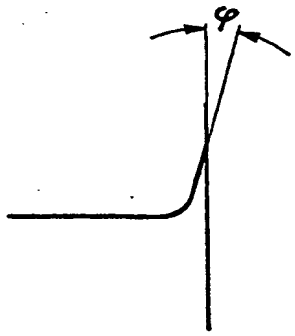


Fig. 1b

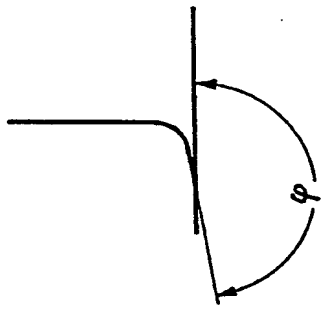


Fig. 2a

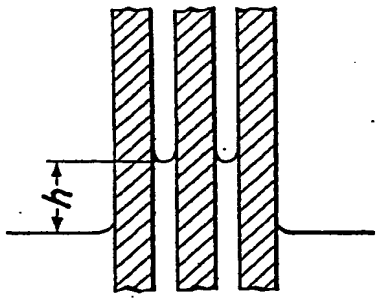
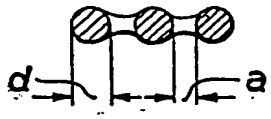


Fig. 2b



1,020,190
2 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

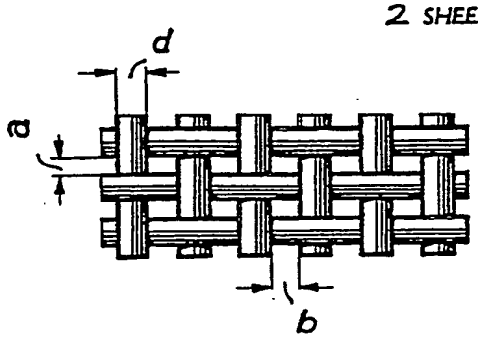


Fig. 3

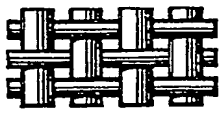


Fig. 5

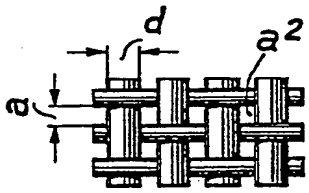


Fig. 4

Fig. 6a

Fig.6c

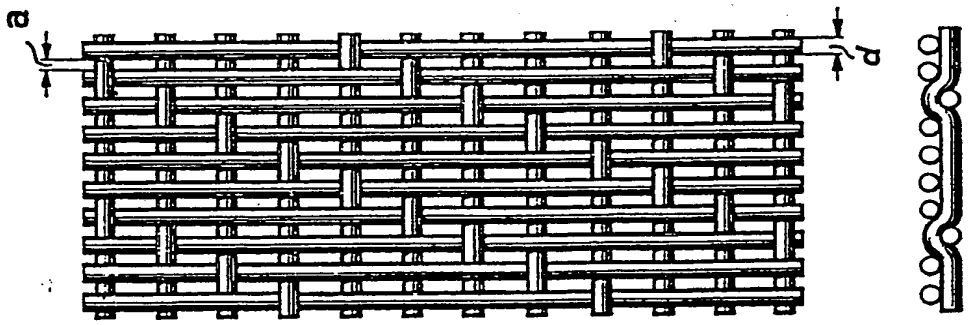
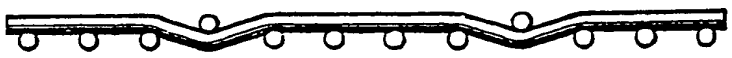


Fig. 6b



2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

Fig. 1a

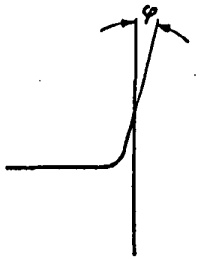


Fig. 1b

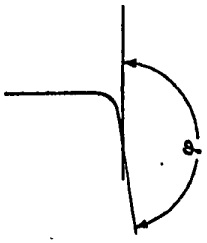


Fig. 2a

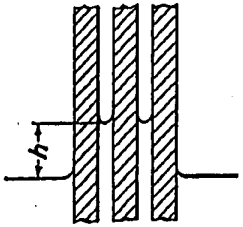


Fig. 2b

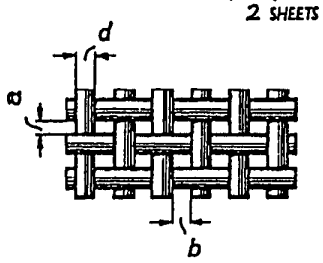


Fig. 3

Fig. 5

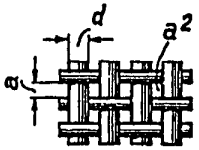


Fig. 4

Fig. 6a

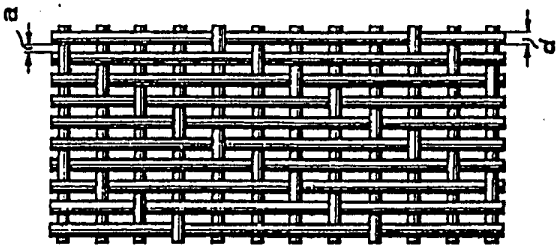


Fig.6c

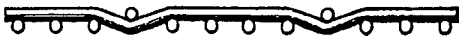



Fig. 6b